
FUEL CELL HANDBOOK
5TH EDITION
OCTOBER 2000

Fuel cells are an important technology for a potentially wide variety of applications including micropower, auxiliary power, transportation power, stationary power for buildings and other distributed generation applications, and central power. These applications will be in a large number of industries worldwide.

This edition of the Fuel Cell Handbook is more comprehensive than previous versions in that it includes several changes. First, calculation examples for fuel cells are included for the wide variety of possible applications. This includes transportation and auxiliary power applications for the first time. In addition, the handbook includes a separate section on alkaline fuel cells. The intermediate temperature solid-state fuel cell section is being developed. In this edition, hybrids are also included as a separate section for the first time. Hybrids are some of the most efficient power plants ever conceived and are actually being demonstrated. Finally, an updated list of fuel cell URLs is included in the Appendix and an updated index assists the reader in locating specific information quickly.

It is an important task that NETL undertakes to provide you with this handbook. We realize it is an important educational and informational tool for a wide audience. We welcome suggestions to improve the handbook.

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PREFACE

Progress continues in fuel cell technology since the previous edition of the Fuel Cell Handbook was published in November 1998. Uppermost, polymer electrolyte fuel cells, molten carbonate fuel cells, and solid oxide fuel cells have been demonstrated at commercial size in power plants. The previously demonstrated phosphoric acid fuel cells have entered the marketplace with more than 220 power plants delivered. Highlighting this commercial entry, the phosphoric acid power plant fleet has demonstrated 95+% availability and several units have passed 40,000 hours of operation. One unit has operated over 49,000 hours.

Early expectations of very low emissions and relatively high efficiencies have been met in power plants with each type of fuel cell. Fuel flexibility has been demonstrated using natural gas, propane, landfill gas, anaerobic digester gas, military logistic fuels, and coal gas, greatly expanding market opportunities. Transportation markets worldwide have shown remarkable interest in fuel cells; nearly every major vehicle manufacturer in the U.S., Europe, and the Far East is supporting development.

This Handbook provides a foundation in fuel cells for persons wanting a better understanding of the technology, its benefits, and the systems issues that influence its application. Trends in technology are discussed, including next-generation concepts that promise ultrahigh efficiency and low cost, while providing exceptionally clean power plant systems. Section 1 summarizes fuel cell progress since the last edition and includes existing power plant nameplate data. Section 2 addresses the thermodynamics of fuel cells to provide an understanding of fuel cell operation at two levels (basic and advanced). Sections 3 through 8 describe the six major fuel cell types and their performance based on cell operating conditions. Alkaline and intermediate solid state fuel cells were added to this edition of the Handbook. New information indicates that manufacturers have stayed with proven cell designs, focusing instead on advancing the system surrounding the fuel cell to lower life cycle costs. Section 9, Fuel Cell Systems, has been significantly revised to characterize near-term and next-generation fuel cell power plant systems at a conceptual level of detail. Section 10 provides examples of practical fuel cell system calculations. A list of fuel cell URLs is included in the Appendix. A new index assists the reader in locating specific information quickly.
